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CONSTITUTION HALL, 525 WEST ALLEGAN, PO BOX 30473, LANSING MI 48909-7973

INTERNET: www.deq.state.mi.us

RUSSELL J. HARDING, Director

REPLY TO:

LAND & WATER MANAGEMENT DIVISION
PO BOX 30458
LANSING MI 48909-7958

December 18, 2001

TO: Janice Tompkins, Nonpoint Source Unit
Surface Water Quality Division, Grand Rapids District Office

FROM: Dave Fongers, Hydrologic Studies Unit
Land and Water Management Division

SUBJECT Pigeon River Model Calibration

As requested, the Hydrologic Studies Unit (HSU) of the Land and Water Management Division (LWMD) has completed its calibration of the Pigeon River hydrologic model. Nothing in this report is an authorization to do any work within the watershed that would require a permit or guarantees that grant proposals based on this report will be permitted or funded.

Preliminary results from this model were presented March 2, 2000. To assist in improving that model, watershed monitoring data were collected from March 22 to August 7, 2000, and were reported to the advisory committee on February 2, 2001. This report discusses the refinements of the model based on additional information and the calibration of the model to the monitoring data.

This report highlights the changes made to the model and the revised results. Appendices A, B, C, and D are attached which detail the basis for the hydrologic characteristics that were incorporated in the model, the calibration process, the refined model parameters, and a comparison of the results from the previous and current model versions, respectively.

Summary

The Pigeon River hydrologic model was revised to refine hydrologic parameters based on calibration data and additional information. River stage was monitored at three locations. There were four good rain events (April 20, May 9, May 18, and May 28, 2000) during the monitoring period. Due to a series of equipment problems, we have reliable monitoring data only for Pigeon River at 128th Street for the latter three rain events. Based on these data, the model reasonably approximates the peak flow data.

Although the model is based on the widely accepted curve number technique, and should therefore be useful for predicting the effects of hydrologic changes in the watershed, we do not consider the model calibrated with only one calibration point. If further calibration of this model is deemed necessary, we will install monitors in the watershed in early April 2002. If this is deemed appropriate, survey work to change the reach routing method to the Modified Puls method would also be performed. Unlike the lag method used in the model, the Modified Puls method attenuates of the flood flows as they move downstream. We regard the lack of this ability as a significant deficiency in the current model, especially downstream of 120th Street where the extensive wetlands should have a significant impact on moderating flood flows.

Model Refinements

The curve numbers were recalculated using our GIS-based system. The land use and soils GIS data used to calculate the curve numbers were reviewed before calculating the curve numbers. Gaps in the data were corrected. The revised curve numbers are shown in Appendix A.

Other changes to the model include:

1. The subbasin previously designated PR1 was split into two subbasins designated Kooiman Drain and B&O@96th. The subbasin previously designated PR3A was split into two subbasins designated PR@108th and PR@120th.
2. The storage coefficient was changed to 1.0 times the time of concentration. Research has indicated that this better replicates average Michigan conditions.
3. The initial loss was changed to the equation available in Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) that is based on the curve number.
4. The precipitation values were updated as shown in Table 1. These values have been multiplied by 0.953 to account for the size of the watershed.

Table 1 – Precipitation Values used in Pigeon River Model

Precipitation Event	Prior Model	Current Model
50% chance (2-year)	2.57"	2.26"
20% chance (5-year)	3.29"	2.86"
10% chance (10-year)	3.81"	3.35"
4% chance (25-year)	4.48"	4.24"
2% chance (50-year)	5.05"	5.02"
1% chance (100-year)	5.62"	5.86"

Results

One of the primary uses of the prior model was to predict the effect of possible additional detention on the flow regime of the Pigeon River, especially at the C&O railroad and West Olive road crossing, with the goal of improving trout habitat as described in the November 1998 report titled "*An ecological assessment of opportunities for fisheries rehabilitation in the Pigeon River, Ottawa County.*" by Mike Wiley and Paul Seelbach. The results from this model and the prior model for the 50, 20, 10, 4, 2, and

1 percent chance (2-, 5-, 10-, 25-, 50-, and 100-year) 24-hour storms are shown in Table 2 for this location. The current model predicts lower peak flows than the former model for every precipitation event simulated. It also predicts lower runoff volumes for every event except the one percent chance storm. This is due to reduced values for most of the precipitation events, increased modeled values for the storage coefficient and initial loss, and modeled refinements in the curve numbers, times of concentration, and lag values. A full comparison of the results of this model to the prior model is included in Appendix D.

Table 2 - Model Results for Pigeon River at West Olive Street

Modeled Flow in Pigeon River at West Olive Street					
24-hour Rainfall	Model	Peak Flow (cfs)	Percent Change	Discharge Volume (acre-feet)	Percent Change
50% chance	Prior	377	-37%	792	-34%
	Current	238		522	
20% chance	Prior	700	-35%	1518	-32%
	Current	453		1033	
10% chance	Prior	972	-32%	2138	-28%
	Current	663		1543	
4% chance	Prior	1362	-19%	3030	-13%
	Current	1104		2634	
2% chance	Prior	1723	-11%	3857	-3%
	Current	1540		3726	
1% chance	Prior	2091	-2%	4703	7%
	Current	2048		5008	

The status of the Pigeon River model will be presented to the Pigeon River Watershed Advisory Committee February 6, 2002. A discussion of possible future modeling work, such as additional calibration monitoring, refinement of the detention goals, and distribution of the model, is anticipated at that time.

If you have any questions or comments regarding this evaluation, please contact me at 517-373-0210.

Attachments

cc: Peggy Weick, Ottawa Conservation District Administrator
Ralph Reznick, SWQD
Ric Sorrell, LWMD
Barry Horney, LWMD

Appendix A
Determination of the Hydrologic Characteristics
Of Pigeon River Watershed

This watershed study was initiated in support of a Part 319 grant intended to improve the Pigeon River watershed. The goal of this study is to better understand the watershed's hydrology to:

- Provide stormwater storage volume goals for each subbasin that will improve fisheries habitat
- Facilitate the selection and design of suitable BMPs
- Predict the effect of the proposed BMPs
- Predict the impact of other hydrologic changes in the Pigeon River watershed

The Pigeon River watershed is entirely within Ottawa County, as shown in Figure 1. The delineated area is 59.5 square miles, as shown in Figure 2. For this report, the subbasins have been given more understandable names. The subbasin previously designated PR1 was split into two subbasins designated Kooiman Drain and B&O@96th. The subbasin previously designated PR3A was split into two subbasins designated PR@108th and PR@120th. The prior and current names are shown in Figures 3 and 4.

The curve numbers for each subbasin were recalculated based on GIS soils and land use data. The land use and soils GIS data used to calculate the curve numbers were reviewed before calculating the curve numbers. Gaps in the data were corrected. The 1978 land use data for the watershed is shown in Figure 5. The Natural Resources Conservation Service (NRCS) soils data for the watershed is shown in Figure 6. Where the soil is given a dual classification, B/D for example, the soil type was selected based on land use. In these cases, the soil type is specified as D for natural land uses or the alternate classification (A, B, or C) for developed land uses, as shown in Figure 7. Runoff curve numbers were calculated from the land use and soil data shown in Figures 5 and 7, respectively. Runoff curve numbers are listed in Appendix C.

The time of concentration for each subbasin, which is the time it takes for water to travel from the hydraulically most distant point in the watershed to the design point, was calculated from the United States Geological Survey (USGS) quadrangles. The HSU of the Department of Environmental Quality defines the storage coefficient as 1.0 times the time of concentration for Michigan. Lag for each reach, which is the travel time of water within each section of the river, is also calculated from the USGS quadrangles. These values are listed in Appendix C.

These parameters were then incorporated into a model using HEC-HMS. The model computes runoff volume and flow. The modeled precipitation events were the 50, 20, 10, 4, 2, and 1 percent chance, 24-hour storms. Design rainfall values for these events are tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129, and summarized for this site in Appendix C.

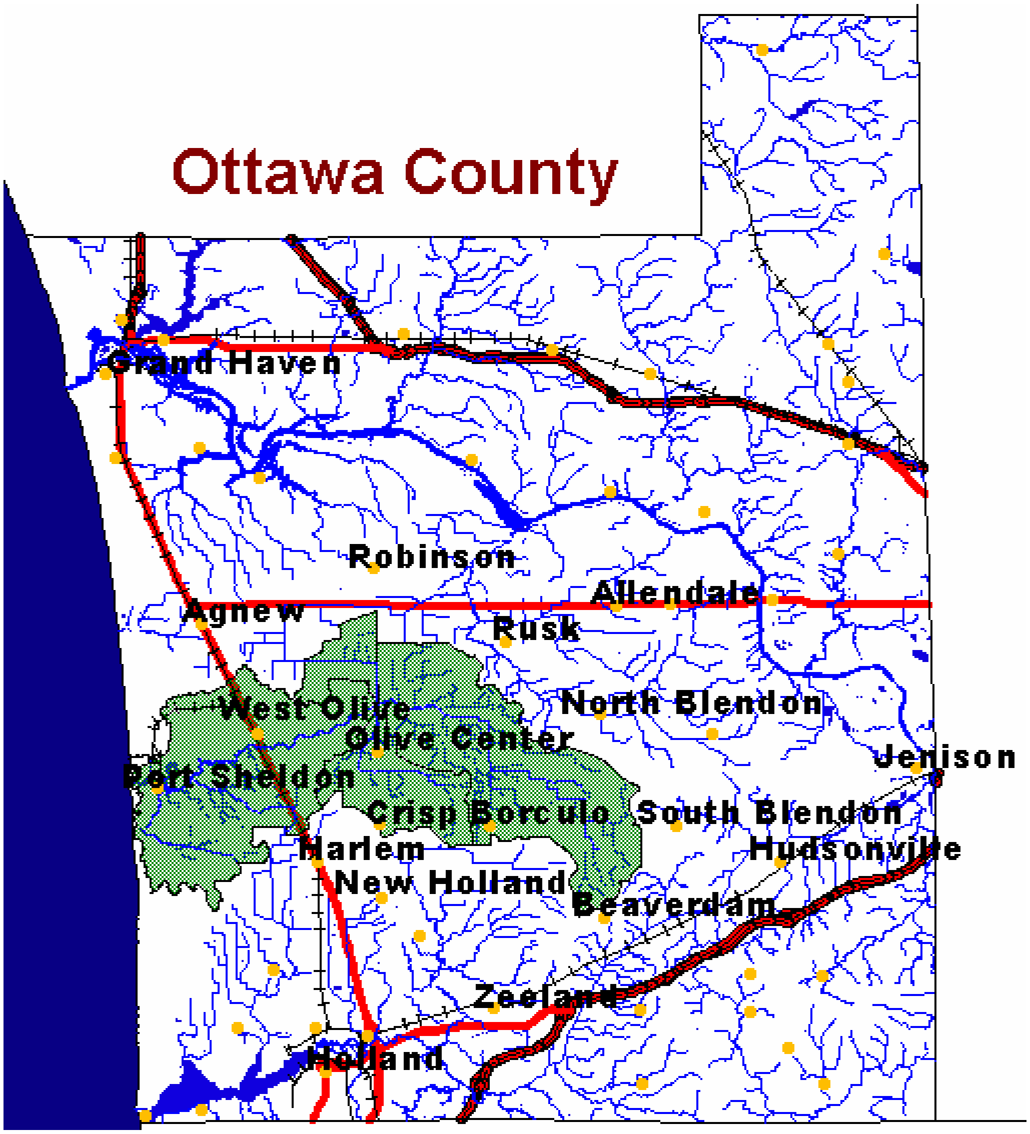

Figure 1: Location of Watershed within Ottawa County

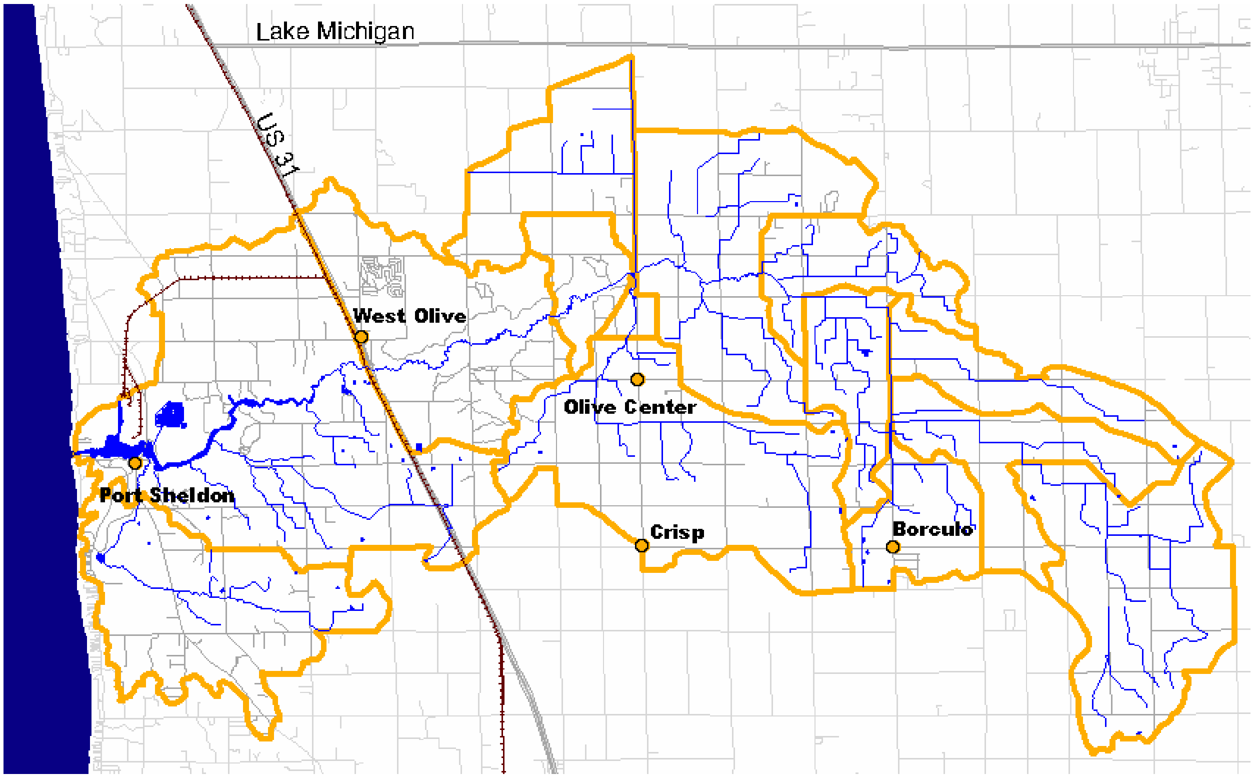

Figure 2: Delineated Watershed

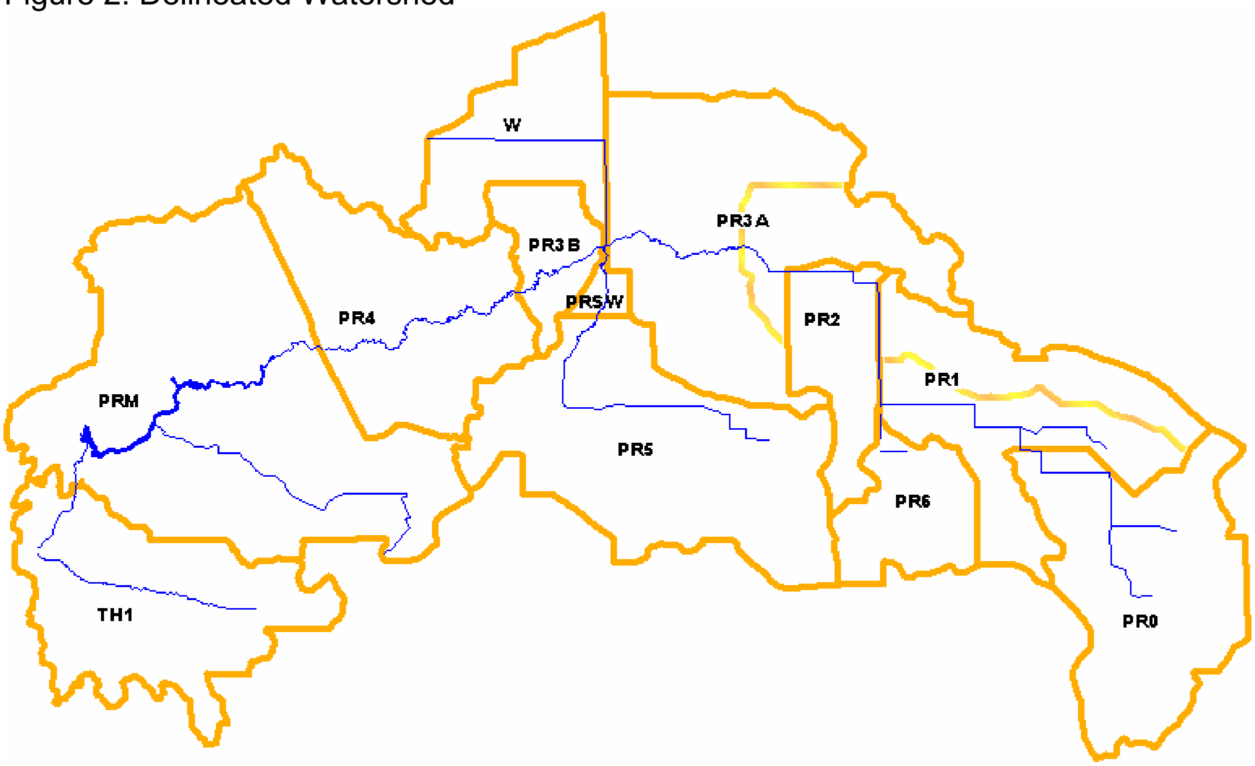

Figure 3: Former Subbasin Names

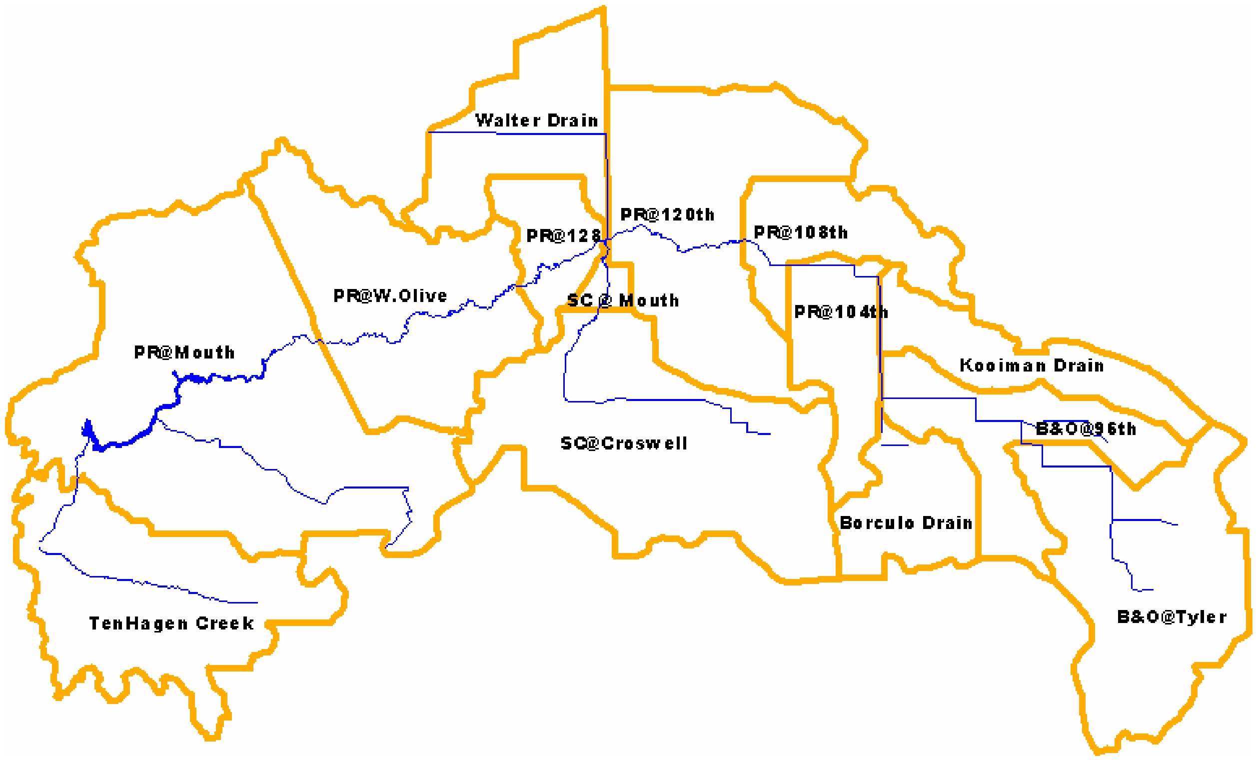

Figure 4: Current Subbasin Labels

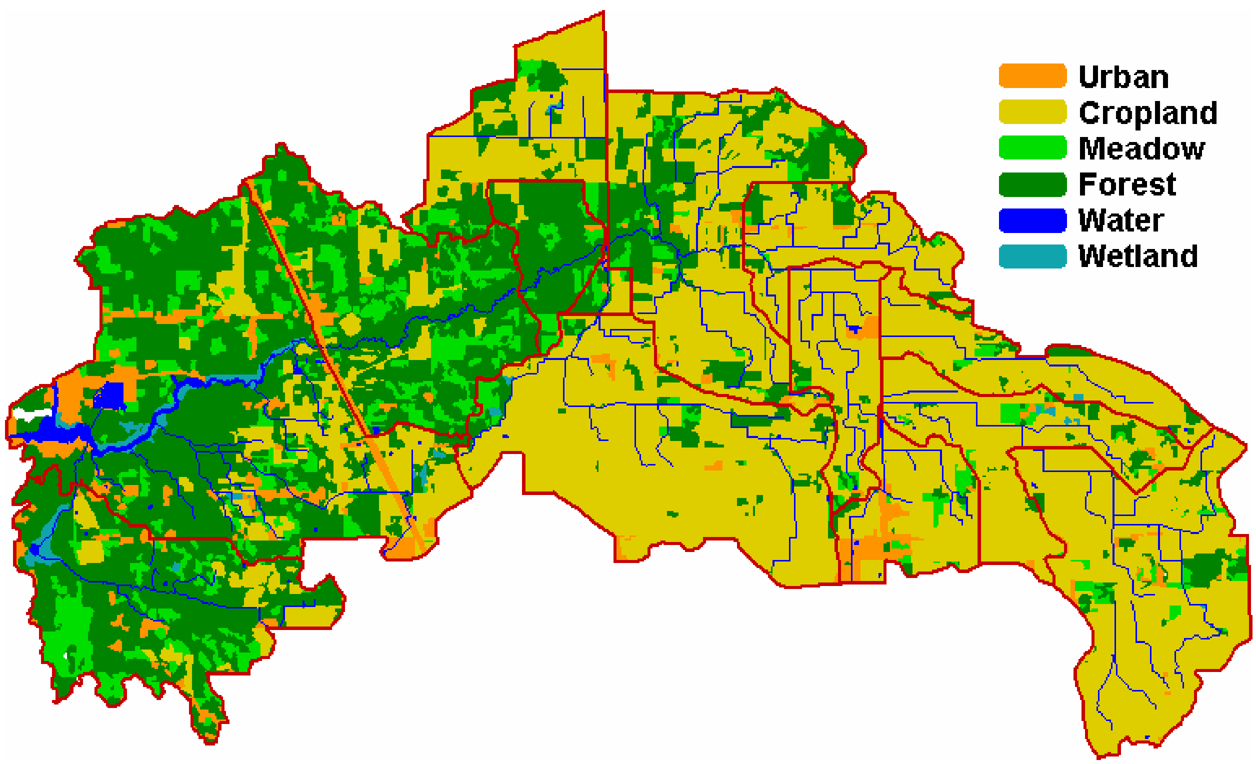

Figure 5 - 1978 Land Use Data

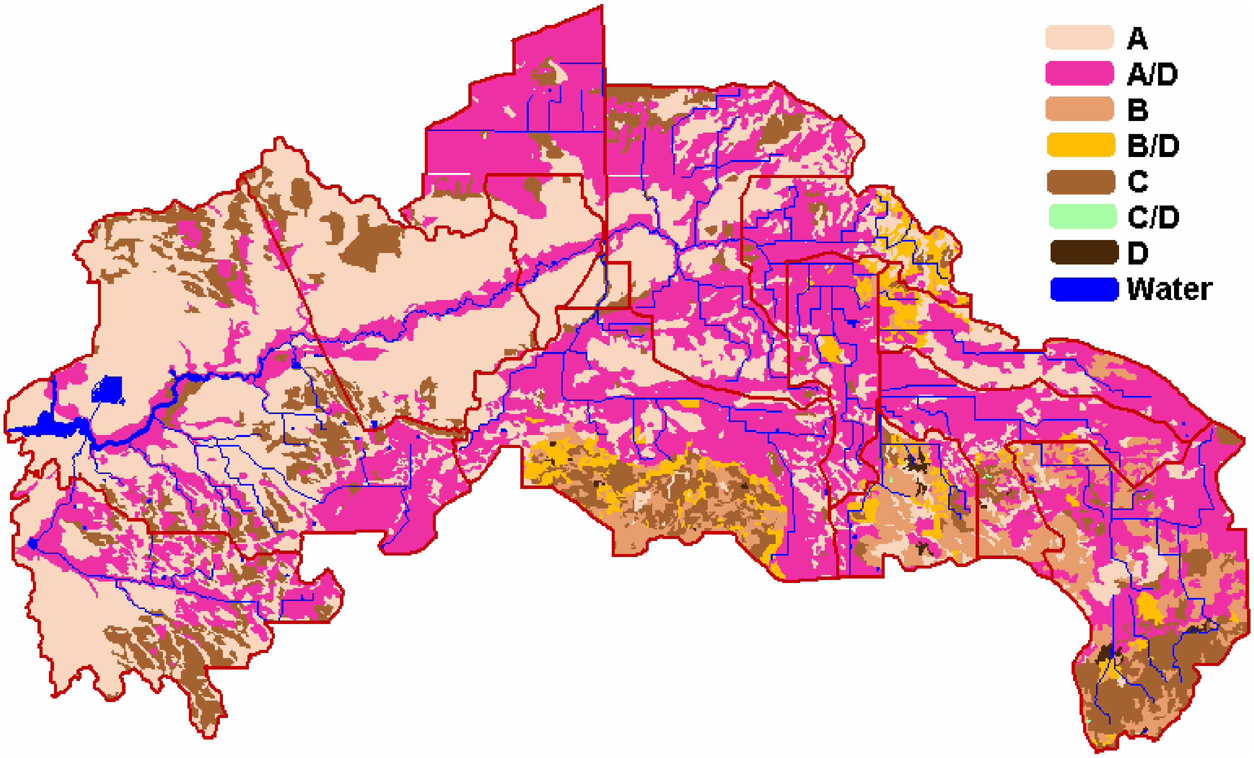

Figure 6: Soils Data

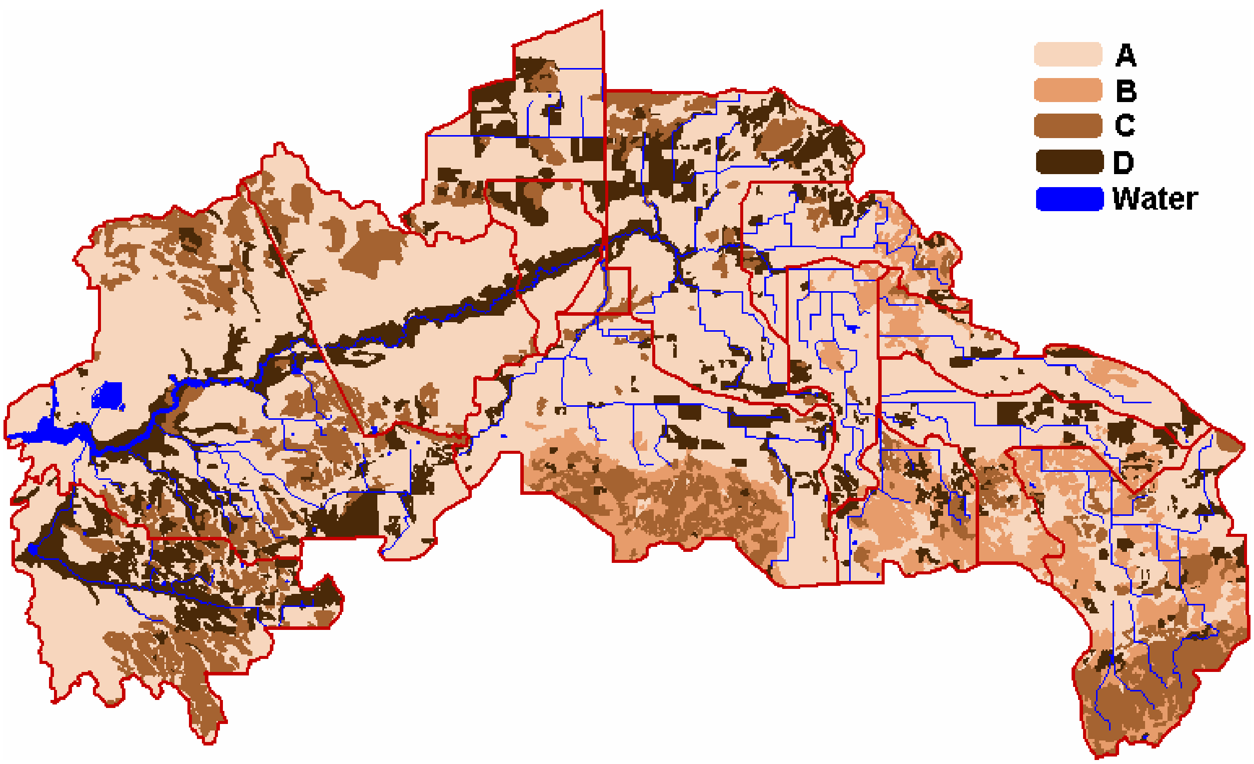

Figure 7: Soils Data, dual classifications modified based on land use

Appendix B

Pigeon River Hydrologic Model Calibration Technical Information

River stage was monitored at three locations using Isco 4230 Bubblers. Precipitation was monitored at one location, near the Ottawa County Parks offices. All of this monitoring data is shown in Figure 1. There were four rain events (April 20, May 9, May 18, and May 28, 2000) during the monitoring period that would have been good calibration events. We also recorded high water marks at four other locations in the watershed following the May 18 storm.

We regard monitoring data for Pigeon River at 128th Street for the May 9, 18, and 28 rain events as the only usable flow data for the following reasons:

- The rain gage data was not operating for the April 20 event.
- The gage for Sawyer Creek at Croswell was working sporadically. Therefore, even the data collected when the gage was apparently working may not be accurate.
- We do not have monitoring data for the third and fourth events at the 104th Street site because of equipment failure.
- The only flows measured at most sites were at or near baseflow. Extension of the rating curves resulted in peak flows based on high water marks from the May 18 storm that decreased from upstream at the Blendon and Olive Drain at Tyler downstream to the 104th Street site. We prefer that rating curves extended by modeling have at least one higher measured flow for comparison.

Precipitation recorded at various gages in the region is shown for the May 18-19 storm in Figure 2. This is an indicator of the variation in rainfall intensity in the watershed and suggests that one rain gage is inadequate for monitoring rainfall in a watershed of this size.

With this in mind, we did compare the model to the 128th Street site's monitoring data for the May 9, 18, and 28 rain events. This data, shown in Figure 4, has been converted from water depth to discharge using the rating curve shown in Figure 3. The comparison to the model's results is shown in Figures 5, 6, and 7. For this comparison only, a baseflow of 50 cubic feet per second (cfs) was included in the model to approximate the baseflow recorded at the site at the time.

The model reproduces the May 9 and 18 peak flows relatively well. The measured flow increases about four hours earlier than the modeled flow. This could be caused by inaccuracies in the 25.5 hours of lag specified for the upstream reaches. The measured flow remains higher than model after the peak. This could be caused by field drains continuing to flow after the surface runoff has ended.

The model does not reproduce the May 28 event well. The modeled flow is significantly less than the measured flow. This could be caused by higher rainfall amounts in the watershed than were recorded at the gage. Higher antecedent moisture than expected after nine days of almost no rain could also account for some of the difference.

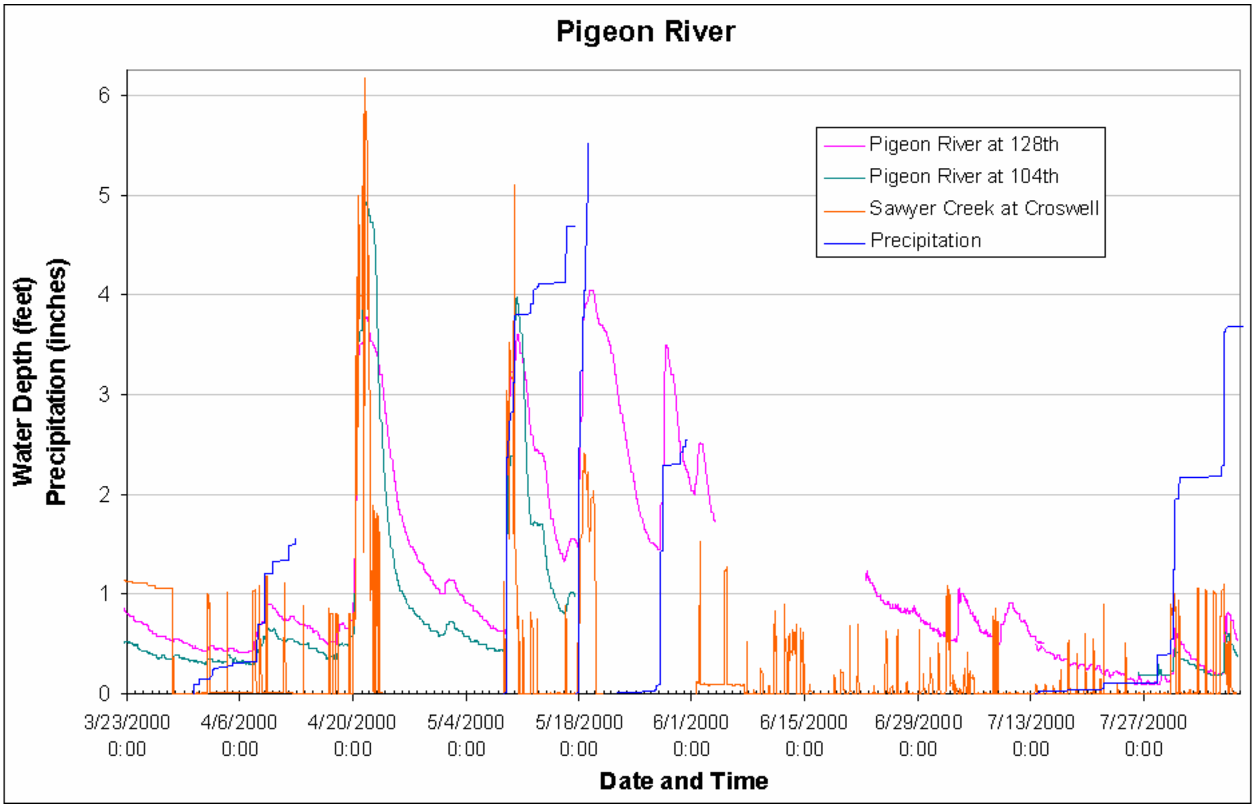

Figure 1: All Monitoring Data

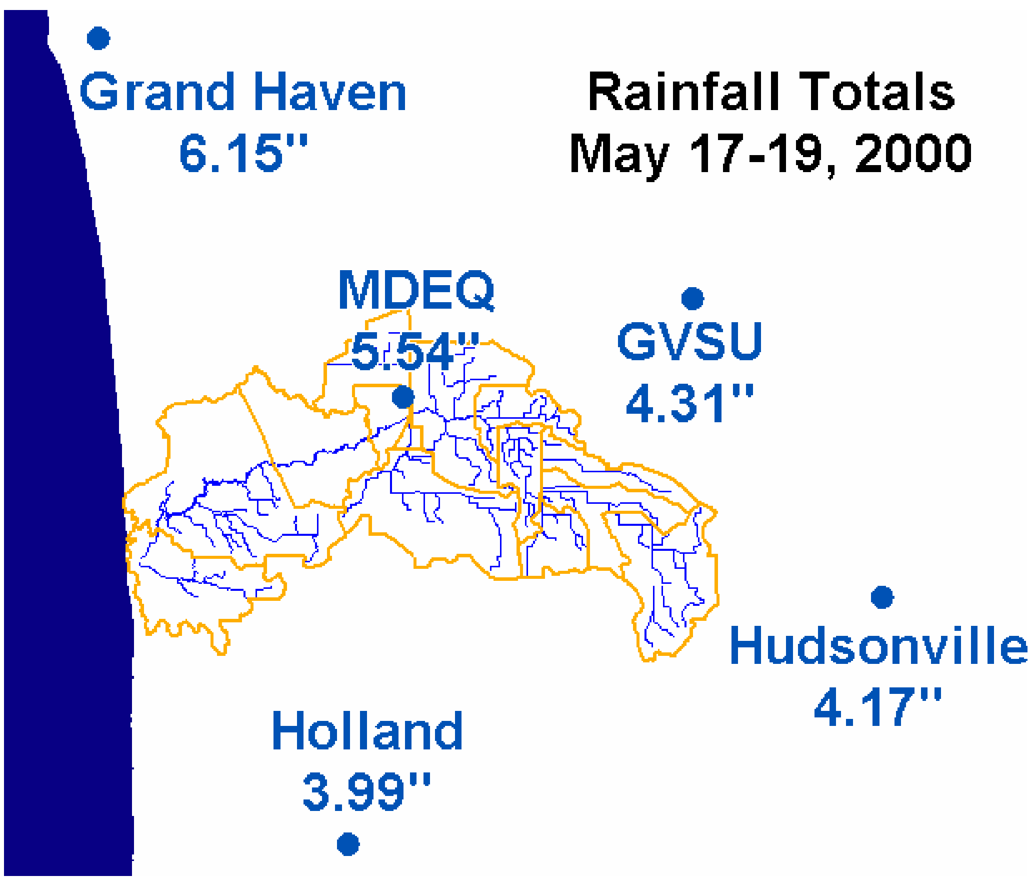

Figure 2: Regional Precipitation Comparison

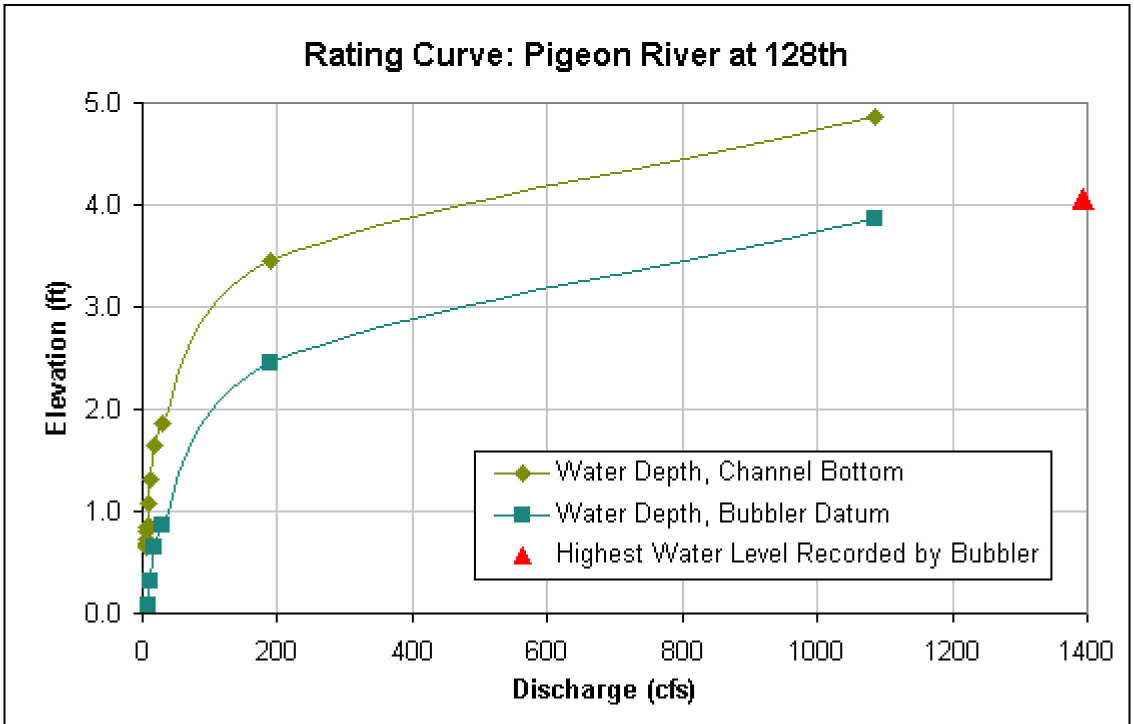

Figure 3: Rating Curve for Pigeon River at 128th Street Site

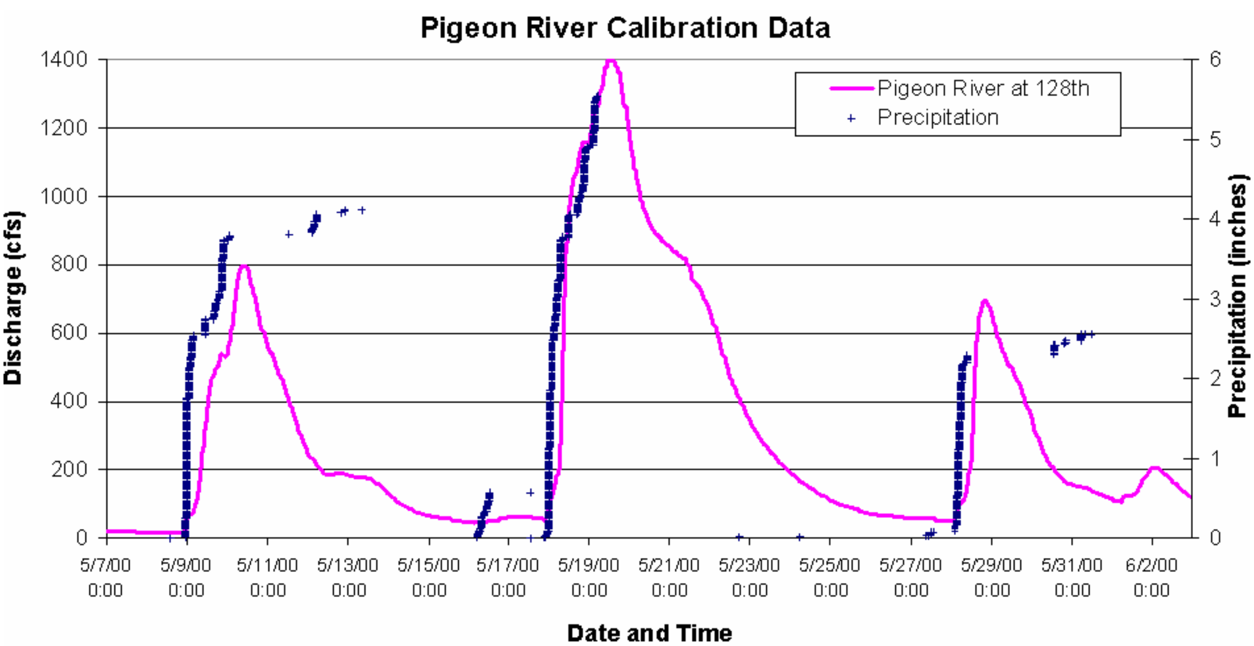

Figure 4: Monitoring data used to calibrate model

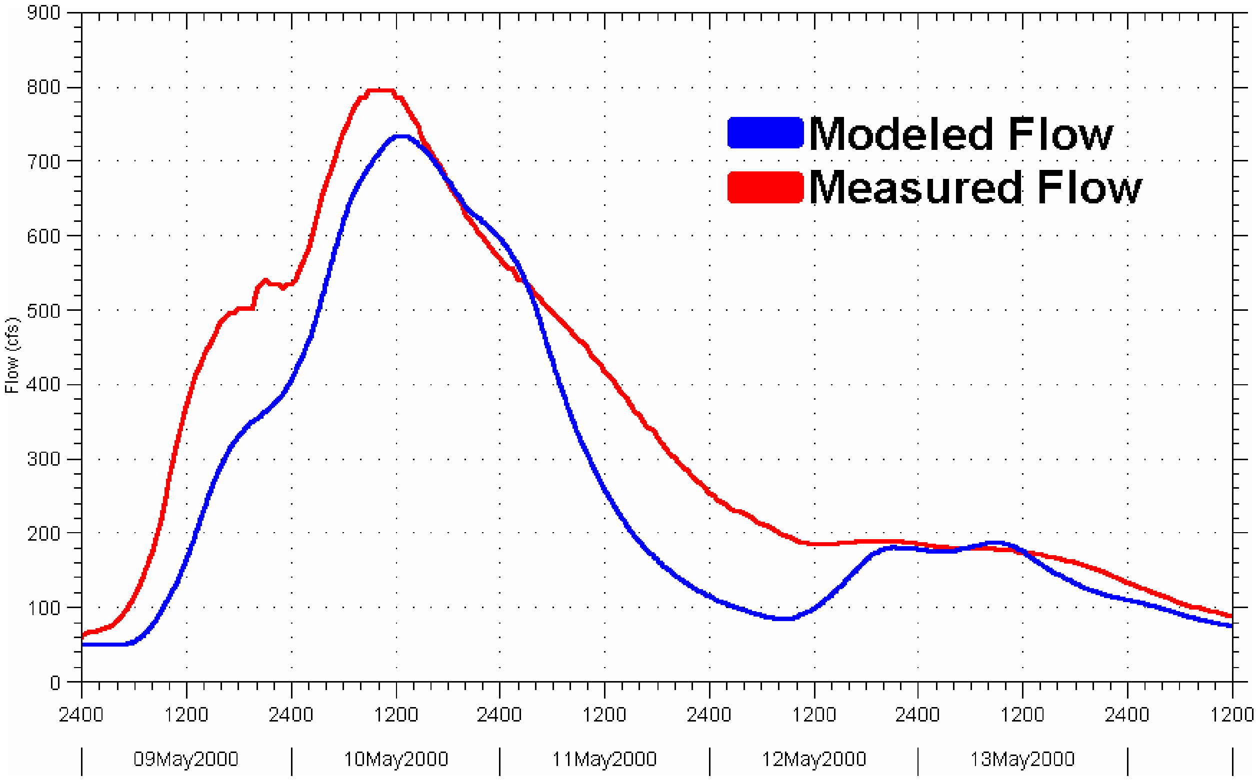

Figure 5: May 9-10 Storm

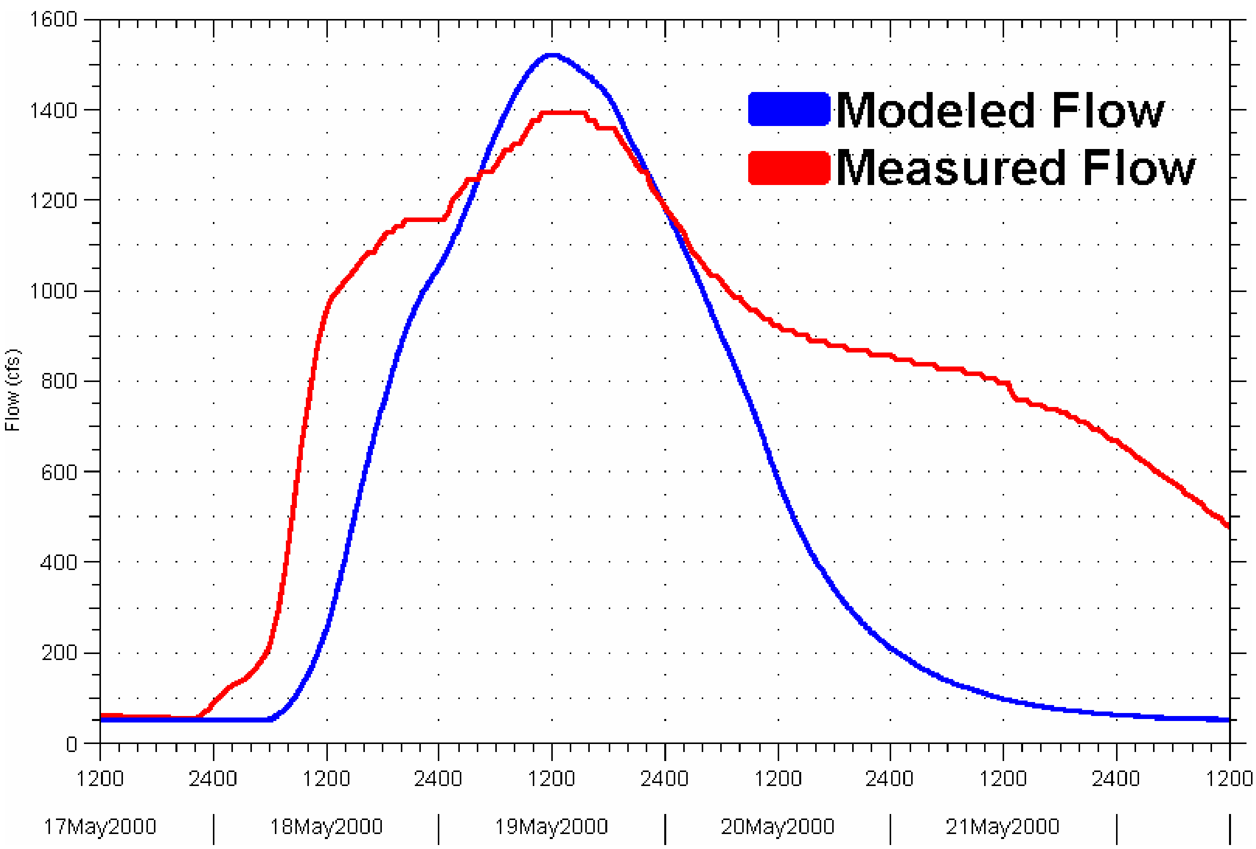

Figure 6: May 18-19 Storm

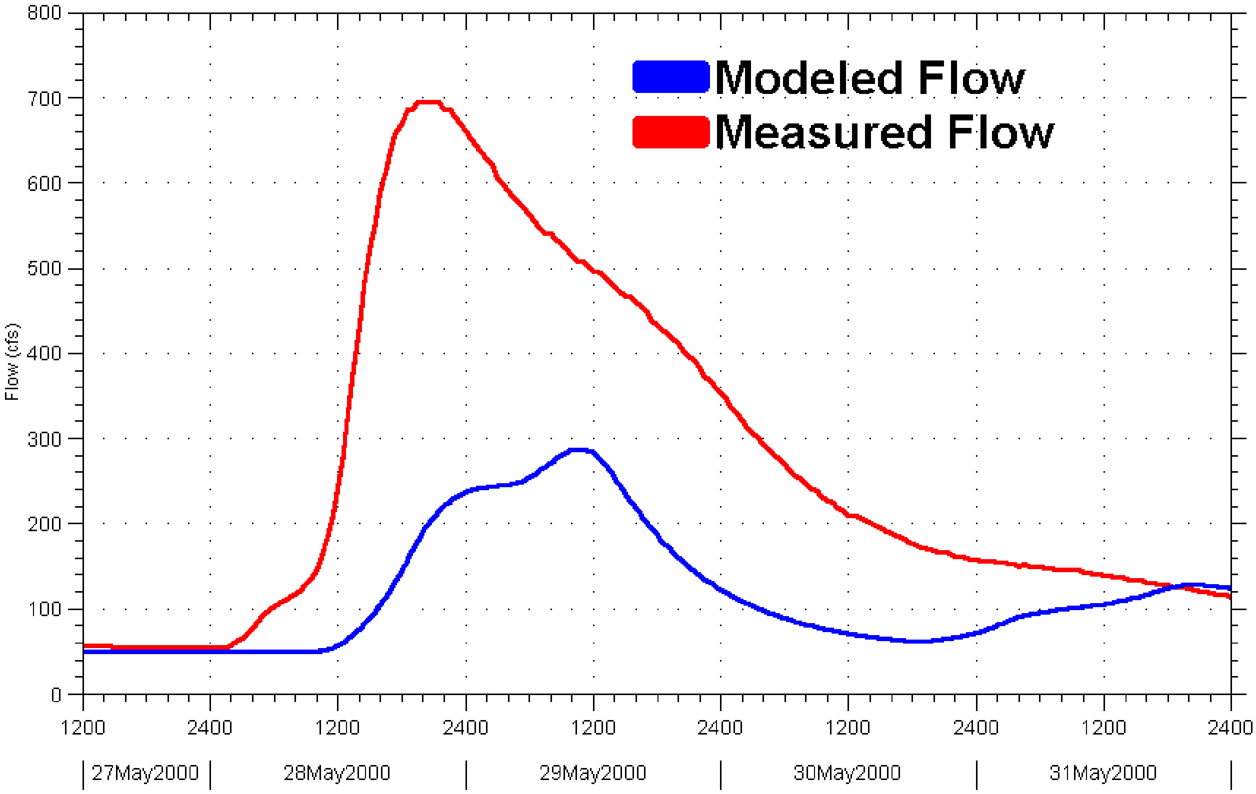

Figure 7: May 27-28 Storm

Appendix C
Pigeon River Hydrologic Model Parameters

This appendix is provided so that the model could be recreated by an engineering consultant, or others, if desired. Table 1 provides the design rainfall values specific to the region of the state where Pigeon River is located. Figures 1 and 2 summarize the hydrologic elements in the HEC-HMS model. Table 2 provides the parameters that were specified for each of these hydrologic elements. Table 3 provides the reach parameters for the Lag routing method. The control specified in HEC-HMS was for a duration of 10 days using a five-minute time interval. The storage coefficient is 1.0 times the time of concentration. The initial loss field is left blank so that HEC-HMS uses the default equation based on the curve number.

Table 1: Design Rainfall Values for Kent County (Region 8)

Rainfall Duration	24-hour rainfall (inches) for given recurrence interval*					
	2-year	5-year	10-year	25-year	50-year	100-year
24-hour	2.26	2.86	3.35	4.24	5.02	5.86
12-hour	1.96	2.49	2.92	3.69	4.36	5.10
6-hour	1.70	2.14	2.52	3.18	3.76	4.39
3-hour	1.45	1.83	2.14	2.72	3.21	3.75
2-hour	1.31	1.66	1.94	2.46	2.92	3.40
1-hour	1.06	1.34	1.57	1.99	2.36	2.75
15-minute	0.61	0.77	0.91	1.14	1.35	1.58
5-minute	0.27	0.34	0.40	0.51	0.60	0.71

*standard values were multiplied by 0.953 to account for the size of the watershed

Table 2: Subbasin Parameters

Subbasin	Area		Curve Number	Time of Concentration (hours)	Storage Coefficient
	Acres	Square Miles			
B&O@96th	2,000	3.12	68	11.19	11.19
B&O@Tyler	3,760	5.87	73	8.42	8.42
Borculo Drain	1,342	2.10	71	7.81	7.81
Kooiman Drain	1,447	2.26	66	11.79	11.79
PR@104th	1,322	2.07	66	7.59	7.59
PR@108th	1,466	2.29	67	6.50	6.50
PR@120th	3,929	6.14	64	10.59	10.59
PR@128th	921	1.44	53	*16.63	*16.63
PR@Mouth	7,639	11.94	60	*36.77	*36.77
PR@W. Olive	3,613	5.65	53	*19.10	*19.10
SC@Croswell	4,842	7.57	69	12.69	12.69
SC@Mouth	195	0.30	55	3.47	3.47
TenHagen Creek	3,549	5.55	59	*16.83	*16.83
Walters Drain	2,056	3.21	64	15.25	15.25
Total	**38,081**	**59.51**			

*Values for time of concentration and storage coefficient were adjusted to account for ponding

Table 3: Channel Reach Parameters

Reach Description	Lag	
	minutes	hours
PR1 (Pigeon River from mouth to TenHagen Creek)	588	9.8
PR2 (Pigeon River from TenHagen Creek to West Olive)	2460	41.0
PR3 (Pigeon River from West Olive to 128th)	534	8.9
PR4 (Pigeon River from 128th to 120th)	258	4.3
PR5 (Pigeon River from 120th to 108th)	354	5.9
PR6 (Pigeon River from 108th to 104th)	84	1.4
PR7 (Pigeon River from 104th to 96th Street crossing)	150	2.5
PR8 (Pigeon River from 96th Street crossing to Borculo Drain)	102	1.7
PR9 (Pigeon River from Borculo Drain to Tyler Street)	420	7.0
SC (Sawyer Creek)	108	1.8
BD (Borculo Drain)	55	0.9

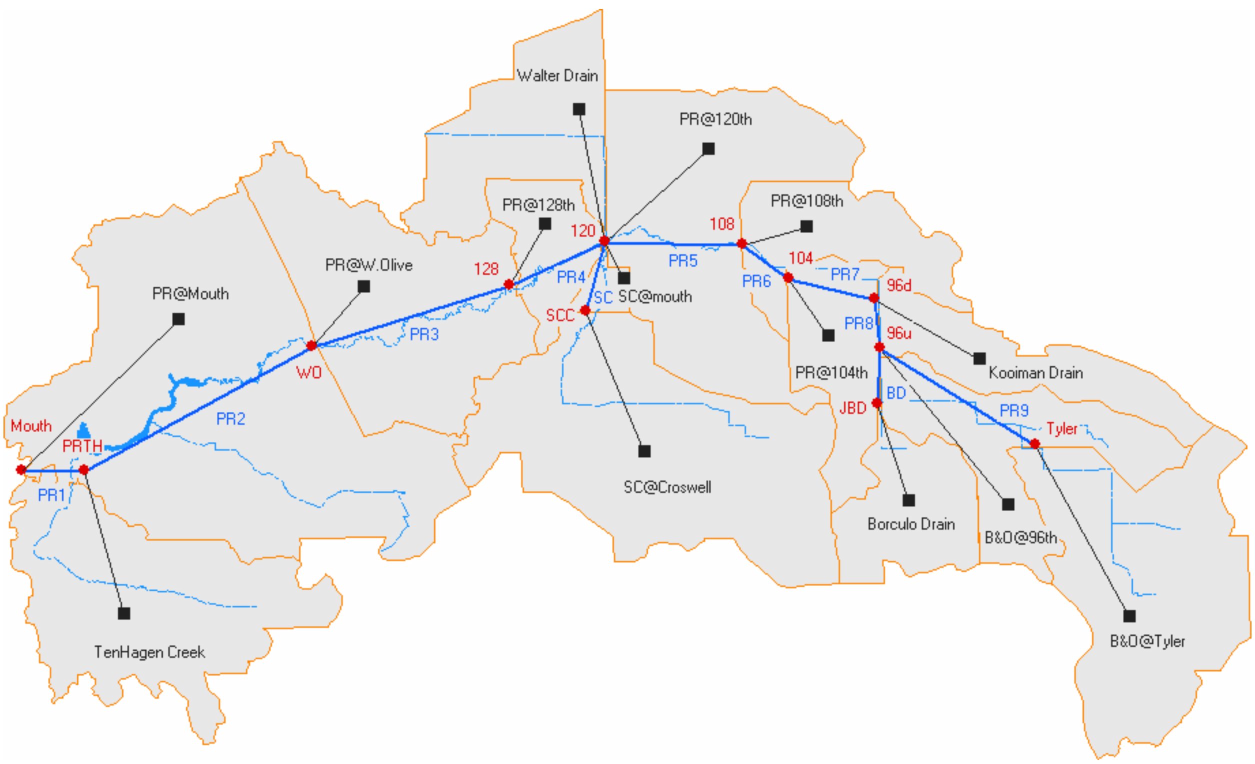

Figure 1: Hydrologic Elements defined for HEC-HMS model

Hydrologic Element Name	Type	Downstream Name	Loss Method	Transform Method	Routing Method
PR@Mouth	SUB	Mouth	SCS	CLARK	
TenHagen Creek	SUB	PRTH	SCS	CLARK	
PR@W.Olive	SUB	WO	SCS	CLARK	
PR2	RCH	PRTH			LAG
PR1	RCH	Mouth			LAG
PRTH	JCT	PR1			
Mouth	JCT				
WO	JCT	PR2			
PR@128th	SUB	128	SCS	CLARK	
PR3	RCH	WO			LAG
128	JCT	PR3			
120	JCT	PR4			
SCC	JCT	SC			
108	JCT	PR5			
96d	JCT	PR7			
96u	JCT	PR8			
Walter Drain	SUB	120	SCS	CLARK	
PR4	RCH	128			LAG
SC	RCH	120			LAG
PR5	RCH	120			LAG
104	JCT	PR6			
PR6	RCH	108			LAG
PR7	RCH	104			LAG
SC@Croswell	SUB	SCC	SCS	CLARK	
SC@mouth	SUB	120	SCS	CLARK	
Tyler	JCT	PR9			
PR9	RCH	96u			LAG
PR8	RCH	96d			LAG
PR@120th	SUB	120	SCS	CLARK	
PR@108th	SUB	108	SCS	CLARK	
PR@104th	SUB	104	SCS	CLARK	
Kooiman Drain	SUB	96d	SCS	CLARK	
B&O@Tyler	SUB	Tyler	SCS	CLARK	
Borculo Drain	SUB	JBD	SCS	CLARK	
B&O@96th	SUB	96u	SCS	CLARK	
BD	RCH	96u			LAG
JBD	JCT	BD			

Figure 2: Hydrologic Element Summary

Appendix D
Pigeon River Hydrologic Model Results:
A Comparison of the Current Model with the Prior Model

Tables 1 through 3 are a comparison of the model results for the current version of the Pigeon River model as compared to the prior version, which was presented to the Pigeon River Technical and Advisory Committees in early 2000.

Direct comparisons of the B&O at 96th, Kooiman Drain, PR at 120th, and PR at 120th subbasins is not possible since these subbasins were combined in the prior model.

Table 1 lists the predicted peak flow from each subbasin. This represents the contribution from that subbasin, not the flow in the river. Table 2 lists the predicted peak flows for selected locations in the river. The target flow listed in Tables 1 and 2 are based on a yield of 4.8 cfs per square mile as described in the November 1998 report titled "*An ecological assessment of opportunities for fisheries rehabilitation in the Pigeon River, Ottawa County*." by Mike Wiley and Paul Seelbach. Table 3 lists the runoff volumes predicted for each subbasin.

Table 1: Predicted Peak Flows from each Subbasin

<table>
<tr><th rowspan="2">Subbasin</th><th rowspan="2">Target Flow (cfs)</th><th colspan="2">Peak Flow (cfs) from 50% chance storm</th><th colspan="2">Peak Flow (cfs) from 20% chance storm</th><th colspan="2">Peak Flow (cfs) from 10% chance storm</th><th colspan="2">Peak Flow (cfs) from 4% chance storm</th><th colspan="2">Peak Flow (cfs) from 2% chance storm</th><th colspan="2">Peak Flow (cfs) from 1% chance storm</th></tr>
<tr><th>Current model</th><th>Prior model</th><th>Current model</th><th>Prior model</th><th>Current model</th><th>Prior model</th><th>Current model</th><th>Prior model</th><th>Current model</th><th>Prior model</th><th>Current model</th><th>Prior model</th></tr>
<tr><td>B&O at Tyler</td><td>28</td><td>98</td><td>132</td><td>176</td><td>236</td><td>250</td><td>321</td><td>401</td><td>440</td><td>546</td><td>548</td><td>712</td><td>658</td></tr>
<tr><td>Borculo Drain</td><td>10</td><td>42</td><td>56</td><td>76</td><td>102</td><td>108</td><td>141</td><td>174</td><td>196</td><td>238</td><td>247</td><td>256</td><td>297</td></tr>
<tr><td>B&O at 96th</td><td>15</td><td>27</td><td rowspan="2">78</td><td>53</td><td rowspan="2">152</td><td>80</td><td rowspan="2">215</td><td>135</td><td rowspan="2">306</td><td>189</td><td rowspan="2">391</td><td>253</td><td rowspan="2">477</td></tr>
<tr><td>Kooiman Drain</td><td>11</td><td>15</td><td>32</td><td>49</td><td>85</td><td>121</td><td>163</td></tr>
<tr><td>PR at 104th</td><td>10</td><td>26</td><td>33</td><td>40</td><td>68</td><td>62</td><td>98</td><td>109</td><td>142</td><td>157</td><td>183</td><td>213</td><td>225</td></tr>
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<tr><td>Walters Drain</td><td>15</td><td>16</td><td>24</td><td>20</td><td>49</td><td>33</td><td>71</td><td>65</td><td>103</td><td>98</td><td>133</td><td>139</td><td>164</td></tr>
<tr><td>SC at Croswell</td><td>36</td><td>65</td><td>116</td><td>125</td><td>215</td><td>184</td><td>298</td><td>307</td><td>416</td><td>427</td><td>523</td><td>568</td><td>633</td></tr>
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<tr><td>PR at 128th</td><td>7</td><td>1</td><td>3</td><td>4</td><td>10</td><td>8</td><td>18</td><td>17</td><td>32</td><td>28</td><td>45</td><td>42</td><td>60</td></tr>
<tr><td>PR at W. Olive</td><td>27</td><td>2.7</td><td>11</td><td>13</td><td>41</td><td>26</td><td>72</td><td>60</td><td>125</td><td>98</td><td>179</td><td>146</td><td>238</td></tr>
<tr><td>TenHagen Creek</td><td>27</td><td>11</td><td></td><td>31</td><td></td><td>53</td><td></td><td>102</td><td></td><td>155</td><td></td><td>219</td><td></td></tr>
<tr><td>PR at Mouth</td><td>57</td><td>14</td><td></td><td>36</td><td></td><td>59</td><td></td><td>113</td><td></td><td>169</td><td></td><td>236</td><td></td></tr>
</table>

Table 2: Predicted Peak Flows at Selected Pigeon River Locations

Location	Target Flow (cfs)	Peak Flow (cfs) from 50% chance storm		Peak Flow (cfs) from 20% chance storm		Peak Flow (cfs) from 10% chance storm		Peak Flow (cfs) from 4% chance storm		Peak Flow (cfs) from 2% chance storm		Peak Flow (cfs) from 1% chance storm	
		Current model	Prior model	Current model	Prior model	Current model	Prior model	Current model	Prior model	Current model	Prior model	Current model	Prior model
96th Street	64	160	221	293	396	421	541	682	745	934	930	1226	1118
104th Street	74	169	233	311	420	447	574	726	792	997	990	1309	1191
120th Street	168	235	376	444	695	645	963	1065	1345	1477	1699	1954	2060
128th Street	175	237	376	446	697	650	968	1076	1354	1494	1712	1980	2077
W. Olive Street	202	238	377	453	700	663	972	1104	1362	1540	1723	2048	2091
Mouth	286	242		463		680		1137		1590		2117	

Table 3: Predicted Runoff Volumes from each Subbasin

Subbasin	Runoff Volume (acre-feet) from 50% chance storm		Runoff Volume (acre-feet) from 20% chance storm		Runoff Volume (acre-feet) from 10% chance storm		Runoff Volume (acre-feet) from 4% chance storm		Runoff Volume (acre-feet) from 2% chance storm		Runoff Volume (acre-feet) from 1% chance storm	
	Current model	Prior model	Current model	Prior model	Current model	Prior model	Current model	Prior model	Current model	Prior model	Current model	Prior model
B&O at Tyler	136	177	238	308	333	415	525	564	710	699	919	834
Borculo Drain	42	59	76	104	108	141	174	193	238	240	311	287
B&O at 96th	47	111	92	212	134	296	224	418	313	529	415	643
Kooiman Drain	28		57		86		148		209		280	
PR at 104th	26	39	53	76	79	107	135	152	191	193	257	236
PR at 108th	32	146	63	290	93	413	157	592	221	758	295	928
PR at 120th	61		131		202		357		513		698	
Walters Drain	16	50	43	103	73	148	140	214	211	276	297	339
SC at Croswell	124	190	235	348	342	480	564	665	782	835	1034	1007
SC at Mouth	1	2	3	5	5	8	10	12	16	17	23	21
PR at 128th	2	4	9	15	18	27	41	45	66	64	99	84
PR at W. Olive	7	16	34	59	70	103	158	176	257	248	382	326
TenHagen Creek	28		74		125		241		363		510	
PR at Mouth	67		172		285		542		808		1130	